AD-A069 981 CALIFORNIA UNIV BERKELEY DEPT OF MECHANICAL ENGINEERING F/G 20/4
APPLICATIONS OF RAYLEIGH SCATTERING TO TURBULENT FLOWS WITH HEA--ETC(U)
1979 L TALBOT, F ROBBEN F44620-76-C-0083

UNCLASSIFIED AFOSR-TR-79-0652 NL

1 OF 1

AD
A069981

END
DATE
FILMED
7--79
DDC

AFOSR-TR- 79-0652

F44620-76-C-0083

LEVEL II

1 5

AD A069981

APPLICATIONS OF RAYLEIGH SCATTERING TO TURBULENT FLOWS WITH HEAT TRANSFER AND COMBUSTION

by

L Talbot and F Robben

University of California Berkeley
Department of Mechanical Engineering
Berkeley, California 94720

Approved for public release; distribution unlimited.

Air Force Office of Scientific Research/NA
Bolling Air Force Base, D C 20332

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

19 REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER 18 AFOSR TR- 79-0652	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER 9
4. TITLE (and Subtitle) 6 APPLICATIONS OF RAYLEIGH SCATTERING TO TURBULENT FLOWS WITH HEAT TRANSFER AND COMBUSTION		5. TYPE OF REPORT & PERIOD COVERED INTERIM rept. 1 Mar 78 - 1 Mar 79
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) 10 L. TALBOT Lawrence, F. ROBBEN Frank		8. CONTRACT OR GRANT NUMBER(s) 15 F44620-76-C-0083
9. PERFORMING ORGANIZATION NAME AND ADDRESS UNIVERSITY OF CALIFORNIA BERKELEY DEPARTMENT OF MECHANICAL ENGINEERING BERKELEY, CA 94720		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 16 2307A3 17 A3 61102F
11. CONTROLLING OFFICE NAME AND ADDRESS AIR FORCE OFFICE OF SCIENTIFIC RESEARCH/NA BLDG 410 BOLLING AIR FORCE BASE, D C 20332		12. REPORT DATE 11 1979
		13. NUMBER OF PAGES 8
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) 12 11p.		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

FLAME PROPAGATION
COMBUSTION IN TURBULENT FLOWS
RAYLEIGH SCATTERING
LASER ANEMOMETRY

400 426 gm

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Further development of instrumentation and data processing techniques to improve Rayleigh scattering and laser doppler anemometry (LDA) as diagnostic techniques in turbulent flows with combustion has continued. A computerized disk operated data acquisition system with 8 channels of 12 bit A/D conversion, a CRT terminal with graphics, and a line printer for permanent copy output has been completed. The data acquisition system was used to study the effect of H_2-air combustion on induced turbulence in a heated boundary layer. Mean, rms fluctuations, probability density functions and autocorrelation were obtained for density and

over

velocity. Three modes of combustion were indicated: 1) surface reaction, 2) surface reaction combined with gas phase reaction, 3) flame-like structure at the edge of the boundary layer. For two studies, 1) the interaction of a flame front with a vortex street and 2) interaction with grid turbulence, a coaxial combustor has been designed to increase the stability of the flame front and to remove background disturbances. In the vortex street study, a hot-wire sensor has been fabricated which monitors the shedding frequency from the vortex generating rod. Fortran programs have been written to monitor turbulent parameters for the vortex and the grid interaction studies.

RESEARCH OBJECTIVES

1. Continuation of development of instrumentation and data processing for Rayleigh scattering and laser anemometry as applied to turbulent flow with combustion and heat transfer.
2. Applications to interaction of a Karman Vortex Street with a plane flame front.
   a. Development of phase-locked techniques to measure convection of discrete vortices through a flame.
   b. Determination of the effect of vortices and flame front curvature on local flame propagation.
   c. Development of numerical techniques to model the passage of discrete vortices through plane flame fronts.
3. Applications to flame fronts propagations in grid turbulence.
   a. Measurement of flame propagation speed as affected by the turbulent flow generated by a grid.
   b. Correlation of flame speed with turbulent parameters such as integral length scales or the Taylor microstructure.
   c. Determination of the effect of combustion on the production and dissipation of turbulence.
4. Applications of Rayleigh scattering laser anemometry diagnostics to turbulent boundary layers through measurements of:
   a. Single point turbulent statistics (e.g. mean and rms fluctuations levels of density and velocity) with and without combustion to determine the effect of combustion on the turbulent flow field.

b. Autocorrelation functions, spectra and two-point correlations to determine spatial characteristics of the structure of turbulence and to determine the effect of the structure on flame propagation and heat transfer.

c. Crosscorrelations (two components of velocity or velocity and density) to determine turbulent transport of momentum and heat.

5. Applications to laminar flow over a heated surface.

a. Development of experimental techniques for measurement of density and velocity profiles for laminar boundary layers over heated surfaces.

STATUS OF RESEARCH EFFORT

In the last year significant progress has been made in all of the Research Objectives described above. This statement of progress follows the order of the Research Objectives format.

1. A computerized data acquisition system based upon a Digital Equipment Corporation (DEC) PCP 11/10 with 28K words of memory has been completed. The computer system is run under a DEC RT-11 operating system using a RK05 disk with 1.25 million works of storage. The system is accessed using either a teletype or a Tektronix 4025 CRT terminal with graphic display capabilities. A line printer is available for output of permanent copies of programs or large data files. Eight channels of 12 bit A/D conversion are available. Samples may be acquired at a constant sampling rate through clock control (up to ~40 kHz for one channel) or individual samples may be initiated by a separate control voltage input by the user. In the latter mode, the time between samples may be continuously monitored by the clock. In addition to these data acquisition capabilities, an interface has been added to the PDP 11/10 to provide for control of stepping motors to be used to move flow field position through the laser optical path for Rayleigh scattering and laser doppler anemometry (LDA) measurements.

In a typical measurement sequence, the diagnostics scan the flow field, calculate mean and rms fluctuation values and display the results graphically on the terminal for monitoring the experiments. Rayleigh signals are sampled at a fixed rate. In the case of LDA signals, measurements are initiated by the signal validation pulses from the frequency tracker and time intervals between measurements are obtained from a

programmable clock. All raw data may be stored on disk memory files for post processing. These data files may also be stored on magnetic tape for processing on a CDC 7600.

The sensitivity of the LDA system for measurement of low velocity has been increased by the use of Bragg cells for frequency shifting. This increased sensitivity is needed to measure transverse velocity components as well as small velocity disturbance levels such as those associated with shedding vortices.

2. A coaxial combustor has been designed to increase the stability of the flame front and to remove background disturbances which might interfere with the interpretation of flame disturbances caused by the Karman vortex street. The flow of the combustible mixture has been limited to an inner jet with air flow in an outer jet. The flow from the outer jet shields the flame fron from mixing processes associated with the interaction of a jet with the stagnant surrounding. The wake downstream of the wall of the inner nozzle has been smoothed using #200 mesh screen. The turbulence level downstream of the combustor is less than 1%.

The use of a phase-locked technique to map the flow field downstream of the vortex street generator rod, requires a stable and reliable sensor to monitor the shedding of vortices from the rod. The use of conventional hot wire-probes and probe supports would introduce disturbances in the flow similar to that of the Karman vortex street; hence those probes cannot be employed. A hot wire design which incorporates a cylindrical tube both as a probe holder and as a wake generator was constructed. The wire sensor, 0.02 mm diameter gold plated tungsten, is welded to 0.5 mm diameter platinum wire supports separated by 6 mm. The sensor portion is

fixed at 1 cm above the cylinder and offset to the side by one cylinder radius.

The reference hot wire has been tested using the computerized data acquisition system. A signal validation scheme has been devised to test whether the vortices are shed with enough regularity for the phase lock technique to be applicable. Computer programs to provide crosscorrelation between either Rayleigh or LDA signals and the reference wire have been completed.

3. The combustor designed for the study of the interaction of a vortex street with plane flame fronts has been adapted so that it may be concurrently used for studies of flame propagation in grid turbulence. Grids with mesh sizes of 1.6 mm and 5 mm have been fabricated for use with the coaxial jet nozzles. Computer programs have been written to compute autocorrelation functions, integral length scales, Taylor microscales and to compare the decay of turbulence with combustion to that reported for isothermal flows.

4. The effect of H_2-Air combustion on induced turbulence in a heated boundary layer has been studied through time and space resolved measurements of velocity (laser Doppler anemometry) and density (Rayleigh scattering). From these measurements mean, rms fluctuations, probability density functions and auto-correlations were obtained by digital processing. The experimental conditions covered equivalence ratios from 0 to 0.3, wall temperature from 1100 to 1300 K and free stream velocity from 14 to 22 m/sec. A typical Reynolds number based on the free stream velocity was 3×10^5. Three modes of combustion were indicated: 1) surface reaction, 2) surface reaction combined with gas phase reaction in the

boundary layer, 3) flame-like structure situated at the edge of the boundary layer. Velocity fluctuations of about 4% in the non-heated boundary layer were reduced to 2% by wall heating. Density fluctuations of 8 to 10% were observed in the heated boundary layer both with and without combustion. From autocorrelation measurements the maximum density gradient region of the flame-like structure was found to fluctuate at a fairly regular rate of 0.5 to 125 Khz depending on various conditions.

5. A detailed study was completed of boundary layer behavior under combustion conditions for lear H_2/air mixtures flowing over a platinum catalytic surface. Regions were identified in which only surface reactions was present and, at higher equivalence ratios and surface temperatures, in which both surface reaction and stable boundary layer combustion occured simultaneously. Surface energy release rates were measured over a range of conditions for both H_2/air and C_3H_8/ air mixtures. From the data it was possible to devise expressions for the surface reaction rate based on simplified surface reaction mechanisms. A more realistic model was developed for catalytic surface reactions which included both finite rate surface oxidation of H_2 to H_2O and radical recombination at the catalytic plate surface. Numerical calculations predicted higher gas phase release rates than were found experimentally. A series of sensitivity tests which were carried out indicated that uncertainties in the gas phase kinetics mechanisms are the most likely cause of the high predicted heat release rates.

PUBLICATIONS

1. Schefer, R.W., Robben, F.S. and Cheng, R.K. Proceedings of the Catalytic Combustion Workshop, North Carolina, 3-4 October, 1978.

2. Schefer, R., Cheng, R., Robben, F. and Brown, N. "Catalyzed Combustion of H_2/air mixtures on a heated platinum plate". Western States Section/The Combustion Institute, Paper No. 78-33 (Boulder, Co., 1978); also Lawrence Berkeley Lab. Report LBL-7801.

3. Schefer, R.W. "Catalyzed Combustion of H_2/air mixtures in flat plate boundary I. Experimental results; II. Numerical Model" submitted December 1978 to Combustion and Flame.

4. Schefer, R.W., Agrawal, Y., Cheng, R.K., Robben, F. and Talbot, L. "Motion of particles in a thermal boundary layer" 3rd International Workshop on Laser Velocimetry, Purdue University, West Lafayette, July 11-13, 1978.

5. Cheng, R., Bill, R., Robben, F. and Talbot, L. "Experimental Study of combustion in a turbulent boundary layer" to be presented at the 2nd Symposium on Turbulent Shear Flows, London, July 1979.

6. Cheng, R.K., Popovich, M.M., Robben, F. and Weinberg, F.J. "Associating Particle Tracking with laser fringe anemometry" submitted to Review of Scientific Instruments.

7. Namer, I., Bill, R., Robben, F. and Talbot, L. "Interaction of a Karman Vortex Street with a Plane Flame Front" in preparation (Combustion and Flame).

8. Bill, R., Cheng, R., Namer, I., Robben, F., and Talbot, L. "Flame Propagation in grid generated turbulence", in preparation (Combustion and Flame).

9. Schefer R.W., Agrawal, Y., Cheng, R., Robben, F. and Talbot, L. "Motion of particles in a thermal boundary layer," in preparation (J. Fluid Mech.).

PROFESSIONAL PERSONNEL

1. Dr. Lawrence Talbot - Professor, Dept. of Mechanical Engineering, University of California, Berkeley.

2. Dr. Frank Robben - Staff, Energy and Environment Division, Lawrence Berkeley Laboratory.

3. Dr. Robert Bill - Assistant Research Engineer, Dept. of Mechanical Engineering, University of California, Berkeley.

4. Mr. Izak Namer - Graduate Research Assistant, Dept. of Mechanical Engineering, University of California, Berkeley.

5. Dr. Robert Cheng - Staff, Energy and Environment Division, Lawrence Berkeley Laboratory.

6. Dr. Robert Schefer - Staff, Energy and Environment Division, Lawrence Berkeley Laboratory.